Making Sense of Space-based Earth Image Data: The KidSat Data System

by Paul M. Andres[1], Laraine Amy[1], Douglas Steinwand[1], Jeffrey Lawson[1] and Russell A. Moffitt[1]

[1]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California

Abstract

The KidSat Data System provided near real-time access to digital images taken from the Space Shuttle. The images were made available to middle school students and teachers across the country and overseas through the World Wide Web. The KidSat Project was one of the first NASA programs to attempt to use the web as a means of distributing image data within minutes of the time they were captured in space. After the first hurdle, getting the image data on-line in a timely manner, was cleared, it became the goal of the Data System to present that data in an understandable context. The development of the system was a collaborative effort. Members of the Data System team conferred continually with teachers, students and other members of the KidSat Project. Modifications to the Data System were made as often as was possible, while attempting to avoid confusing the users. The goal was to create a on-line system that presented the KidSat images in a manner that allowed the students to better understand and interpret these images. In short, that goal was reached, but whether the users agreed with this judgment may be directly related to the speed with which they could connect to the Internet. Many lessons were learned along the way, and strategies for future similar projects were devised. For the three KidSat missions over 1500 images were captured and made available on the Data System. Additionally, meta-data describing the Shuttle location and orientation, satellite weather data (captured at or near the time of the KidSat image) and digital maps of the area directly surrounding the KidSat image were made available. How these various data sets were assembled and how effectively design and operational goals were met is discussed in detail.

I. Introduction -

The KidSat Project provided middle school students around the nation with the necessary tools to study the Earth using a remote-sensing instrument, just as astronauts and scientists do during Space Shuttle missions. The project involved mounting a digital camera onboard the Space Shuttle. The middle school students could then request that the camera capture an image at a particular time by submitting an image request over the Internet. The requests were routed to the Mission Operations Gateway at the University of California, San Diego (UCSD), and then to NASA's Mission Control Center at the Johnson Space Center (JSC) in Houston Texas. Image data were returned the KidSat Data System at the Jet Propulsion Laboratory (JPL) in Pasadena, California. The images could then be accessed in classrooms, using the Internet, and studied and analyzed by the students. The students could download the image and create enhanced image products. These student-enhanced images could then be returned to the Data System so that students could see each other's discoveries.

The KidSat Project was made up of five elements: Space, Mission Operations, Data, Exploration and most importantly Education. The project was managed by the Jet Propulsion Lab, where the Space, Data and Exploration elements were based. The Mission Operations element was managed by University of California, San Diego. The Education element was managed by Johns Hopkins University's (JHU) Institute for the Academic Advancement of Youth (IAAY).

The KidSat Data System was responsible for acquiring, archiving, and making accessible the data that was returned from the KidSat Flight System. Additionally, the Data System was responsible for providing the students and teachers with image processing tools allowing them to manipulate the digital images. And finally, the Data System personnel were responsible for providing technical support to the students and teachers. All of this was to be done while attempting to incorporate the efforts of young people at every level and using mostly

endured, the overall experience was a very rewarding one for both the students and professional members of the team. The Data System has integrated a number of image data sets and display techniques that allow teachers and students to make better sense of the nadir looking KidSat images. (see Figure 1)
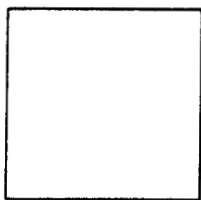

Figure 1: The set of images of the Northeastern coast of Australia demonstrate how the KidSat Data System helped the students and teachers "make sense" of the nadir looking image data. On the left is the original nadir looking image. In the center, the image is scaled, rotated and placed in a context of another image data set. On the right the center image is used as a texture map, draped over elevation data and reoriented to a more familiar oblique perspective. Users of the Data System have access to these data sets and display techniques through the Data System web site. These data sets and display techniques are available for ALL KidSat images.

The Data System successfully supported each of the three KidSat Shuttle flights, STS-76, March of 1996, STS-81, January of 1997 and STS-86, September of 1997, and continues to serve all of the 1500 plus images returned from those three flights. Each of the images is available at full resolution, 3060 x 2036 pixels and is supplemented with a significant amount of supporting image data. These supporting data were provided, as demonstrated in Figure 1, in an attempt to create a clear visual context for the nadir looking earth images captured from the Shuttle. This visual context was created with the hope that it would allow the students and teachers to better understand and interpret the KidSat images. They could then further explore any image that sparked their curiosity. This paper will discuss how the Data System requirements were met, what worked and what did not. The paper will discuss possible alternate strategies that might be used in similar circumstances. (This paper contains only a few color images, however a URL for a digital version[1] that contains all color images as well as URL's to web pages that illustrate the ideas being discussed throughout the paper are included.)

II. Data Flow

The Data System was the repository for many different data sets for the KidSat Project. The primary data were the image data received from the Space Shuttle through NASA's Johnson Space Center (JSC) and the meta-data received from University of California, San Diego (UCSD) during the KidSat flights. All additional image data were linked directly to the original image data. By combining the original image data, the meta-data and the supporting image data a broader context, in which the image data could be better understood and interpreted, was created. In the following sections the details of the data flow from JSC and UCSD and the processing steps carried out in association with each of those flows is discussed.

A.   Image Data From JSC to JPL

Once the data arrived at JSC, it was made available to members of the Data System Team. The data were transferred to JSC directly from the Shuttle. The transfer from the Shuttle normally took place during the "night" half of the ninety minute orbit. The path of the data on the ground at JSC evolved over the three KidSat missions.

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[1] The digital version of this paper can be found at http://kidsat.jpl.nasa.gov/datasys/journal_paper.html
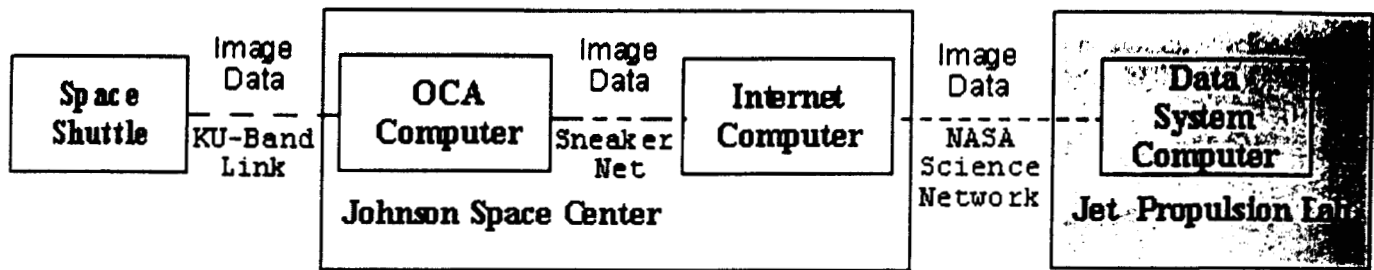
Figure 2: The diagram above shows the flow of the data from the Shuttle to the Data System as it existed for the first KidSat mission. Data System team members were required to be in Houston to accept the files from the OCA computer and transfer them to the Data System computer.

During the first flight student members of the Data System team were stationed at JSC (see Figure 2). As the data were transferred from the Shuttle to the ground a "sneaker net" was used to transfer the data from the Orbiter Communications Adapter (OCA) Computer to a "Internet Computer". The "sneaker net" acted to isolate the OCA computer from the Internet and consisted of transferring the data between the computers on a removable hard disk. The students copied all of the images off of the removable hard disk and then passed the disk on to the UCSD students. After the Data Team students had handed-off the removable hard disk, they would then commence the transfer of the image data files to the Jet Propulsion Lab (JPL). The students used a simple Windows FTP client and moved the files from their Internet computer at JSC to a specific location on the Data System computer at JPL. The connection between JSC and JPL made use of the dedicated NASA Science Network (NSN) connections between the two NASA centers.

During the second flight student members of the Data System team were again sent to JSC in order to support the transfer of the image data to the Data System at JPL (see Figure 3). The hardware supporting the process changed significantly. The image files were now transferred from the OCA machine to a File Server by JSC personnel. This transfer took place via local area network. The OCA Computer was now isolated from the Internet by a firewall rather than the sneaker net used in the first mission. This decreased the time required to transfer the files. For the first half of the mission the students transferred the files from the File Server to the Data System computer at JPL. During the second half of the mission the same procedure was performed by students and personnel at JPL. The directory on the File Server was monitored remotely and the data were pulled across as soon as they were placed on the File Server.
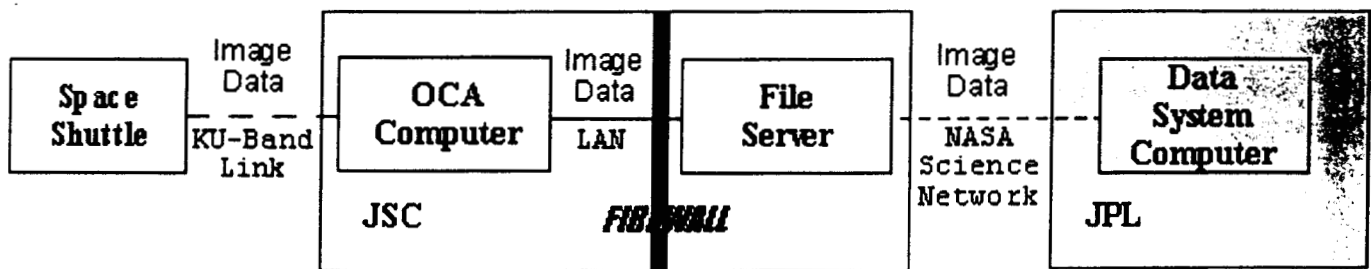

Figure 3: This diagram shows the changes that occurred at JSC that allowed the Data System team members to move the data from the File Server computer without having to be in Houston. This configuration supported flights two and three.

By the third flight the transfer of the data from JSC was completely automated. A program was written to monitor the contents of the directory on the File Server. The contents of the data directory were captured and compared with the data that had already been transferred. Image files that had not been transferred were then transferred from the File Server to the Data System computer. A change in the flight software compressed the

image files on the Shuttle prior to transfer to JSC. This shortened the file transfer times both from the Shuttle to JSC and from JSC to JPL. However, a decompression step was now required at JPL.

B.   Processing Image Data at JPL

The 6 megabyte image files were transferred from JSC to JPL in no less than 90 seconds and in no more than 300 seconds. The Data System was required to process the images as fast or faster than they were transferred to the Data System from JSC. In the next section the steps taken to process a KidSat image and place it on the web are examined. The software and hardware involved in that processing are also discussed. Each KidSat image was processed as follows:

- decompress the Kodak Image File (KDK)
- read and parse KDK header,
- convert KDK to Tagged Image File Format (TIFF),
- convert TIFF to Portable Pixel Map (PPM) format,
- contrast enhance PPM file,
- generate reduced resolution PPM files,
- move full and reduced resolution PPM files to the KidSat web server.

This processing was carried out on one of two computers. The data were then transferred to a second computer that served the data on the web. The diagram (Figure 4) below shows the flow of data as well as the specifics about the computers used to perform each task.
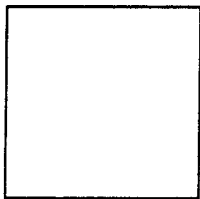
Figure 4: For each of the three KidSat missions an SGI Crimson Class machine with an R4400 CPU and 192 MB of RAM was used to process the image data from original to final format. The computer used as the Web Server changed after the first flight from a Sun Sparc 2 to a Sun Ultra Sparc with 2 CPU's running at 168 MHz and 256 MB of RAM. This machine handled all KidSat web traffic and CGI-BIN processing

The details and timing of each of the processing steps follows below and are summarized in Figure 5.

The first step in the systematic processing of the images was to decompress the KDK files. The KidSat camera flight software was altered prior to the third flight in order to make better use of the onboard disk space and downlink bandwidth resources. On average the file size was reduced by a factor of two. The decompression of a KDK image file took on average less than 5 seconds to complete.

Following decompression, the KDK header information was read and parsed. When the camera captured an image the time and several camera parameters were written in the header of the KDK file. The camera parameters included some useful information: shutter speed, aperture setting, and lens focal length, and some less useful information: the exposure compensation, the focus area and the drive mode. All of this information was read and placed in a record of the Sybase database being used to track the images in the Data System. The time required to parse, and write the information to the database was less than 5 seconds per image.

The KidSat image files were now converted from the native Kodak format (KDK) to a standard Tagged Image File Format (TIFF). The uncompressed KDK files were 6 megabyte files. The CCD in the Kodak camera was a 2048 x 3072 pixel array. As part of converting these KDK files to TIFF, the color information of the 6 megabyte files was interpolated to yield RGB 18 megabyte files. The algorithms used to perform this color interpolation were detailed in the Kodak DCS 460 Programmer's Reference manual[2]. The resulting file is a 24 bit color image. A UNIX version of the software that performed this conversion was written. Converting one image

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[2] Kodak Digital Science, Kodak Professional Digital Camera System. Programmer's Reference Manual Models: DCS420m, DCS 420c, DCS 460m, DCS 460c, DCS 465m, DCS 465c, NC2000, EOS-DCS 1, EOS-DCS 3, ES-DCS 5. November 1995.

from KDK to TIFF required 60 seconds[3]. The resulting full-resolution TIFF files were 3060 x 2036 pixels in size. The conversion program cropped 6 pixels from the border of the image in order to avoid any interpolation artifacts that might have been introduced at the edge of the image.

Following the conversion to the TIFF format the images were converted again. This second conversion was carried out so that the images on the Web Server could be stored in an easily processed image file format. The TIFF images were converted to Portable Pixel Map (PPM) image files using one of the programs found in the freely available netpbm library[4]. The conversion from TIFF to PPM file required less than 10 seconds. The conversion to the PPM format was chosen due to the availability of the netpbm routines.
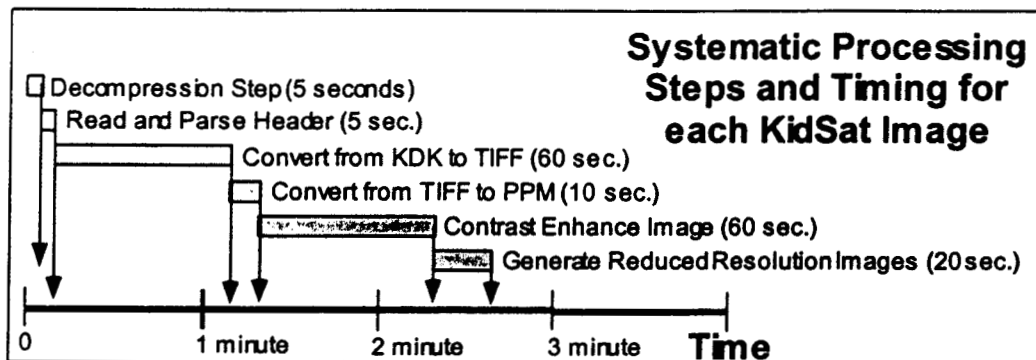

Figure 5: To the left, the steps and the timing of each step involved in the processing of each KidSat image. The total time required for the processing of one image was slightly more than 150 seconds.

Because we had no access to the digital images taken on previous Space Shuttle missions, we had no prior hands on experience with such images. Also, because getting the images to the students as quickly as possible was a requirement no image enhancement was performed on the first images captured by the Shuttle. However, roughly 15 minutes after the first images appeared online the KidSat Principal Investigator stated that the images could be improved significantly if they were processed with Adobe Photoshop. Subsequently, the contrast was adjusted on all of the images from the first half of the first flight by stretching the images based on the maximum and minimum intensity values found in the green band. The green band was chosen because within the color CCD in the KidSat camera there are twice as many GREEN filtered pixels as there are RED and BLUE filtered pixels. This contrast enhancement step was then added to the systematic processing of the incoming images so that it would be performed automatically after the images were converted from TIFF to PPM. The contrast enhancement process changed several times between the first and the third flight. For the third flight the contrast enhancement process consisted of taking the PPM file and separating the RED, GREEN and BLUE planes, stretching each of the planes independently using a percent stretch[5] and then recombining the three planes to form a color image (see Figure 6). In most cases this seemed to generate a bright and reasonably accurate color representation of the area photographed although it resulted in several images with extreme coloring. These few extreme cases led to discussions with the Digital Image Lab Personnel from JSC. It was concluded that no systematic contrast enhancement would yield outstanding results for every image. The process used for the third flight was deemed satisfactory. The contrast enhancement required nearly a minute of processing time to complete, because it separated the three bands of the image, stretched them individually and then recombined them.

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[3] SGI Crimson class machine (CPU: MIPS R4400 Processor Revision 5.0 with 192 MB RAM)

[4] http://sunsite.unc.edu/pub/X11/contrib/utilities/netpbm-1mar1994.p1.tar.gz - NetPBM . The netpbm set of programs is a LARGE collection of programs and utilities for manipulating images. They include many converters, and image enhancement tools.

[5] A percent stretch in this context refers to a contrast enhancement where a certain percentage of the pixels at the top and the bottom of the distribution are saturated. In this specific case 0.5% saturation at both high and low ends.

Figure 6: This pair of images demonstrates the effect of performing contrast enhancement on the original image files. The image on the left is the original image. The image on the right is the contrast enhanced image. The enhancement process separates the three bands of the RGB image and stretches them independently and then recombines them to produce the final product. This image was taken during the first KidSat flight on March 30, 1996 near city of Bhopal in India. The center of the image is near 22.2N Latitude, 78.9E Longitude.

Following the contrast enhancement two lower resolution versions of the full-resolution contrast enhanced image were created. These lower resolution image files were used to gain faster access to the image data in its display on the KidSat Data System web pages. The lower resolution versions included a 1/4 resolution image that was 765 x 509 pixels (width and height respectively) and a thumbnail that was 96 x 64 pixels. The three different resolutions were then transferred to the Data System web server and made available online. The generation of these two reduced resolution images required roughly 20 seconds. The total time to complete the processing of one image from reading the KDK header to placing the full and reduced resolution, contrast enhanced PPM files on the KidSat web server was roughly 150 seconds or 2.5 minutes (as seen in Figure 5) . Therefore, when the transfer of the images slowed to greater than 150 seconds the processing time requirement could be met, but when the transfer of the images required only 90 seconds the systematic processing of the images fell behind the transfer process. Although this meant that images were not being processed as fast as they were being transferred the delay was not significant. Indeed given the intermittent nature of the data transfer, (image files were transferred during the "night half" of the 90 minute shuttle orbit) , the processing of images from one orbit was generally completed before the arrival of images from the next orbit.

In addition to the systematic processing of the KidSat images a final step involving the image data were the writing of the image files in their original format to CD-Write Once (CD-WO) media. This archive step was performed as a backup so that any data on-line could be re-created using the CD-WO disk and the programs that made up the systematic process.

C.   Meta-Data from UCSD to JPL

In addition to receiving the image data from JSC the Data System received meta-data from UCSD. The operations team at UCSD collected the Shuttle telemetry from JSC. The telemetry data and the time stamp associated with a particular image was processed and placed in a data record within a file. Each data record contained information about both the image and the Shuttle. The Shuttle information specifies where the Shuttle was at the time the image was taken and includes the following: the altitude, the pitch, roll, and yaw, the nadir latitude and longitude and the orbit number. Using both the Shuttle position and the student request the following information was compiled: the time the image was taken, the school(s) that requested the image, the student designated geographic name of the image, the reason for requesting the image, the image length, width, center latitude, center longitude and rotation angle. Individual data records were grouped by orbit number and

a Generated Annotation (GA) file was sent to the Data System. Nominally, a GA was sent to the Data System no fewer than three different times:

1. at the time the Camera Control File was sent up to the Shuttle,
2. after the images were retrieved from the Shuttle and
3. after the Shuttle telemetry information had been processed.

The processing of the GA file was handled automatically, triggered by the receipt of an e-mail notification message. This notification message specified the location of the GA file and a checksum value of the file. The checksum value was verified, to insure that the file was properly transferred. The GA file was then parsed for syntax errors and if no errors were found the data were read into the database where they were associated with a KidSat image and made available online. During the first mission the telemetry information was associated with an image by its mission event time (MET). For subsequent missions, an ID was placed in the image header as well as the telemetry information to make a match between telemetry and image much easier. The meta-data from the GA file as well as from the image file header was parsed and inserted into a table in a Sybase RDBMS by C and Perl programs via calls to stored procedures using Sybase client libraries. Upon completion of processing the GA file an e-mail reply was sent to UCSD. This reply indicated whether or not the GA was found and processed successfully and if not what the apparent problem was and what action should have followed.


III.   Generation of Supplementary Image Products to Support KidSat Images

Following a successful first flight, during which more than 300 images were processed and placed online for the students, it became clear that a large part of the Data System's responsibility was to help the students and teachers "make sense" of these images. Therefore, the Data System expanded its systematic processing to include the generation of supplementary image products. These supplementary products were associated with individual KidSat images. The associations were primarily geographical (center latitude and longitude). However, temporal associations were also made with weather data that was collected during the second and third KidSat flights. These supplementary image products were added in the hope that they would provide a rich context in which the KidSat images could be better understood. In the following sections, the generation of these supplementary image products is discussed, and how these products are then integrated into the Data System is described.

A. Digital Raster Maps

As the first KidSat Mission unfolded it became obvious to all involved that an independent geo-referenced global data set would be very helpful. This independent data set could be used to verify the pointing of the camera on the Shuttle as well as aid the students and teachers in the classroom by providing a more familiar look at the area surrounding their requested image. Students in the classrooms attempted to use a variety of maps including school atlases to pinpoint the location of the images. At Buist Academy in Charleston, South
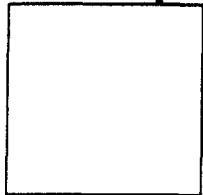
A. JNC Map   B. Satellite Weather Data

C. Satellite Data Map   D. JNC Map draped over elevation data

Figure 7: This set of images shows an example of (A)the JNC map, (B)a section of the
global weather map, nominally taken within 90 minutes of the KidSat image of
interest, (the diamonds on the map represent images available within the Data
System) (C) the satellite image map, showing shaded relief, and (D) the JNC draped
over the elevation data (used within a VRML plug-in, allowing interactive
manipulation of the 3-D data set). These four supplementary data sets are created
for each KidSat image for which a center latitude and longitude are known. These
four are associated with the image of north-eastern Australia, STS086.ESC.08023638,
center lat. 21.4S and center long. 149.3E.

Carolina the students used a set of Operational Navigation Charts (ONC's)[6] to determine image location and the
characteristics of the surrounding area. This was obviously a special case but this special case needed to be made
more accessible. So, members of the Data System team began to generate Jet Navigation Charts (JNC's)[7] for the
areas surrounding individual KidSat images (see Figure 7 A). These JNC's are a 1:2,000,000 scale representation of
the Earth and are available on CD-ROM[8] for the entire area covered by the KidSat camera.

After it became clear that these JNC's would be beneficial to everyone it became a goal to generate a map for
every KidSat image. The JNC CD-ROMs for the KidSat coverage area (60° North latitude to 60° South latitude)
were placed online in a 100 disk CD-ROM Jukebox. Using the center latitude and longitude information in the
GA file a map was constructed for every KidSat image. These individual JNC maps were created to be 400 km on
a side. This 400km X 400km JNC is placed on-line as a 1024x1024 pixel image file, giving the online maps a
resolution of about 400 m/pixel. These JNC's provide further geographic context for the associated KidSat image.
The JNC's are of a proper scale so that users can make use of the map's annotation. Countries, states and
provinces, cities, towns and mountains, as well as shaded relief, contours and elevation values are all labeled on
the JNC maps. Students could use this annotated information to annotate the associated KidSat image. The JNC's
had the additional benefit of being a geo-referenced data set. Given the latitude and longitude range of the
individual JNCs other supplementary data sets could be generated with the identical latitude and longitude
range.

B. Global Weather Maps

Following the first KidSat flight Dr. Sanjay Limaye of the Space Science and Engineering Center (SSEC) at
the University of Wisconsin was contacted to discuss a possible collaboration. The SSEC collects satellite weather
data from around the world and the Data System wanted to inquire about the possibility of SSEC supporting
future missions with this data. An agreement was reached to capture weather satellite data from GOES 8 and 9,

[6] Operational Navigation Charts (ONC) are designed to satisfy the en route visual and radar requirements of pilots/navigators
flying at medium altitudes. Topographic Base Map. Hydrography, prominent landmarks, contours and spot heights in feet,
layer tints, shaded relief, towns, principle roads, railways, high tension power lines, and cultural features. Aeronautical
Overlay, Aerodromes, radio facilities, aeronautical and marine lights, obstructions, isogonals, maximum terrain elevations, or
maximum elevation figures. 1 to 1,000,000 scale.
[7] Jet Navigation Charts (JNC) are long range navigation charts specifically designed to meet the requirements of users in high
altitudes and high speed aircraft. Each chart combines extensive area coverage with the depiction of detail required for
navigation by radar, celestial navigation and dead reckoning.
[8] ARC Digitized Raster Graphics Coverage, produced by Defense Mapping Agency Aerospace Center St. Louis, MO

MeteoSat and GMS-5 weather satellites and generate high resolution global weather mosaics every three hours during the period of time the KidSat camera is mounted in the Shuttle window. These global mosaics had a spatial resolution of 8 km/pixel. The global weather maps were then used to give the students and teachers a view of the weather surrounding the location of a specific KidSat image (see Figure 7 B) at or around the time of that specific KidSat image. The weather data would ordinarily be captured no more than 90 minutes before or after any KidSat image. The high resolution image data were transferred from SSEC to JPL automatically as it was created. The images were then moved to KidSat web site. Scripts were written to automatically crop the appropriate piece from the weather map taken nearest in time to any particular KidSat image. Therefore providing both a geographic and a temporal context for any KidSat image.

C. Digital Satellite Maps

Following the completion of the third mission a global satellite map was made available to KidSat. The map, with a resolution of 1 km/pixel, provided shaded relief, cloud-free and natural color view from space for every KidSat image[9] (see Figure 7 C). The generation of the satellite maps for each KidSat image was significantly more straightforward than the generation of the JNC's. The global satellite map was in the form of one large image file. The latitude and longitude ranges of the JNC's were read and the corresponding area was cut from the satellite image map. The shaded relief and the natural color found in these maps allows the students to better identify large features seen in the KidSat images. Students are able to better determine image orientation given this additional geographic context.

D. Elevation Maps

Low resolution global elevation data were made available to KidSat after the completion of the third flight. The 1 km/pixel elevation map covering the identical area as the JNC and the cloud-free satellite maps was created for every KidSat image[10]. The elevation data were not made available to the users but instead were processed with other information in order to generate more advanced products. The elevation data were used in the generation of three dimensional rendered views for the area surrounding each KidSat image (see Figure 7 D). The JNC or cloud-free satellite maps with or without the registered KidSat image were draped over the elevation data generating 3-D Virtual Reality Modeling Language (VRML) worlds. These 3-D VRML[11] worlds can be manipulated interactively within a web browser using the Cosmo Player Plug-In[12] (or any other VRML 2.0 plug-in). This interaction allows the students and teachers to understand the topography of the KidSat image and its surrounding area. The students can also view the image and its surroundings from the any perspective in order to better understand the KidSat image and the features therein. The production of the elevation data maps was similar to that of the cloud-free satellite maps. The latitude and longitude ranges of the JNC's were read and the corresponding area was cut from the appropriate elevation map tile. If the desired area fell on the boundary of two or four tiles, the appropriate tiles were first concatenated and then the area was cut from this mosaic of tiles.

III. Supporting Mission Operations

The individual data components that were used in the KidSat Data System have now been described. In this section the discussion will focus on: the use of these data components to support Mission Operations, the monitoring of the Data System during the three KidSat Shuttle Flights, and the use of additional resources in the attempt to support the students and teachers.

Starting with the second KidSat flight the generation of the JNC's became an important part of Mission Operations support. The Mission Operations Group at UCSD used JNC's and the associated KidSat calibration

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[9] http://kidsat.jpl.nasa.gov/cgi-bin/uncgi/ks_imageview?dzs=maps&bestname=STS086.ESC.08023638&onoff=92

[10] http://kidsat.jpl.nasa.gov/cgi-bin/uncgi/ks_imageview?dzs=maps&bestname=STS076.ESC.01002520&onoff=284

[11] Virtual Reality Modeling Language

[12] http://cosmosoftware.com/

images to determine if the pointing of the camera was as expected. The calibration photos were chosen to include a geographic feature clearly visible from the Shuttle. Generally, this meant a coastline, an island or a large lake. UCSD requested a JNC map by specifying the center latitude and longitude of the desired area. The requests were made via email and were processed by programs activated by their arrival. The JNC's were then generated. UCSD was notified that the request had been processed and that the JNC's were available. Theoretically, this entire process required no human intervention, however during the flights all of the automatic processes were monitored by a member of the Data System. Upon receipt of the JNC's the Mission Operations Group at UCSD would determine how far off-center the KidSat image was in the JNC map. If the KidSat image was within 100 to 200 pixels of the center of the JNC the camera pointing was considered within an acceptable error range. If the image was found to be outside the acceptable error range the Mission Operations Group would attempt to determine the cause of the error and subsequently recalculate the center latitude and longitude if the error was found. In some cases errors were caused by erroneous telemetry information, these errors were corrected following completion of the mission using telemetry playback systems located at JSC.

The monitoring of the Data System during flight operations required that the flow of the image data from JSC, the meta-data from UCSD and the weather data from SSEC be checked continually. The Data System was monitored around the clock while the KidSat camera was mounted and taking images onboard the Shuttle. In addition to tracking the flow of data to the Data System, the processing of that data and requests for additional data were also closely watched during operations. Processing problems were handled internally while data transfer problems were dealt with immediately and directly via telephone. Generally speaking and certainly by the third flight Data System operations required minimal intervention.

Obviously, good communications during any mission operations support activities are critical. Communications between the Data System and the others elements of the KidSat Project during mission operations were carried out either over the phone, via fax, via email or in person. The availability of listen-only voice loops also allowed the Data System monitors to follow various conversations between different parties at JSC, at UCSD and onboard the Shuttle. In an attempt to extend the communications lines to the students and teachers in the schools a CU-See Me reflector was created to support communications between students at the Data System, Mission Operations at UCSD and the classrooms. However, this attempt to further communications with the classrooms may have been more of a distraction to the students than a benefit. Students often appeared more taken with the technology and interacting with previously unknown persons than with actually using the technology to communicate their ideas and request needed information. This may have been due to lack of teacher and student training. Additionally, means for synchronous and asynchronous communications between classrooms were provided via Internet Relay Chat (IRC) and a KidSat message board. This allowed teachers and students to communicate and share information in real-time or near real-time.

In an attempt to allow the students, teachers and the public to virtually visit a selected image location special visualization products were produced, usually during the camera downtime[13], recorded to videotape and released to the students, teachers and public via NASA TV. One press release video product was made for each of the three flights. The video products were produced as part of a collaborative effort between members of the KidSat Project, students involved in the Exploration Team and members of the Solar System Visualization (SSV) Project at JPL.

IV. Supporting Students, Teachers and Public during and between Missions - Web Site Interactions

The interface for nearly all interaction between students, teachers, members of the public and the KidSat Data System is the Data System Web Site[14]. Because this was the primary interface it was crucial that the web site be designed and implemented with the Data System requirements and several key facts in mind:

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[13] The three KidSat flights were all on Shuttle-Mir docking missions. The camera was mounted for roughly 24 hours prior to docking, taken out of the window during the docking, and then re-mounted for about 40 hours after un-docking. The period of time spent docked to Mir was roughly 5 days.

[14] http://kidsat.jpl.nasa.gov/datasys/

1. the primary customers were middle school students,
2. technology in the average middle school lags 1-3 generations behind current technology (including bandwidth to the Internet) and
3. accessing and acquiring images and supporting data should be as intuitive as possible.

The KidSat images are certainly the centerpiece of the Data System if not the entire project. Clear and easy to use paths for accessing these impressive images of the Earth needed to be provided Several paths to the image data were created in the hope that each of the paths would help the users find a particular image or set of images depending on the search criteria. Using the various interfaces available on the Data System web site students in the classrooms can search for individual images in the following ways:

1. geographically using a point and click map-based interface,
2. using a fill-out form to specify either a simple or complex query to the database,
3. using an interactive list that allows the users to sort the list based on the contents of any of the list columns as well as viewing the list as text or thumbnail images or
4. by looking through the "Latest Images" which are organized so that the most recently processed images are displayed first.

When the user selects the image(s) that they wish to explore further they are then presented with numerous options. They can examine the image more closely by zooming and panning on the area(s) of interest. They can look at the meta-data associated with image. They can look at the associated satellite weather image, the JNC map or the satellite map that surrounds the image. If they choose to view one of the surrounding area maps, they can then composite a scaled and rotated view of the image on top of the map.   They can even adjust the registration of the image to the map interactively and create a VRML 3-D textured landscape. At any point the students may select to download the image they are currently examining. They may then choose the size and the image file format they wish to download. The class that requested a particular image was required to validate the meta-data associated with the image and submit their input back to the Data System via fill-out form. Students could pursue their image investigations further by either submitting annotated images or image explorations to the Data System web site. Again these student submissions were uploaded to the Data System using HTML fill-out forms and file upload capabilities available since HTML version 2.0. Additionally, the Data System web page offers a brief overview of the workings of the web pages, more detailed help pages and links to related projects web pages. (Figure 12 demonstrates some supporting data associated with each image)

During the initial phase of the KidSat Project web pages were served from an available UNIX workstation In order to ensure that students were given first access to the data a second site was set up for the public. Prior to the second flight the web pages were moved to a more powerful UNIX web server. Given the increased speed of the new server the decision was made to allow the public to view the web pages from the same server and the secondary site was eliminated. Maximum traffic seen on the KidSat website at JPL was 90,000 hits in a day. This rate was generally seen during and shortly after the KidSat camera was mounted in the window of the Shuttle. Within days of mission completion the access rate dropped significantly to about 3,000 hits a day. A detailed look at these pages, how they worked to support the KidSat project, and a discussion of issues that arose during their use will be covered in the following paragraphs.

As previously mentioned many KidSat schools had limited access to the Internet and this was a major focus of the Web Site design. To deliver 3000 x 2000 pixel images to students with no more than shared ISDN access (128 kbps) in the best case and 14.4 kbps modem access in the worst case is a significant challenge. All of the pages that display image data can be modified to accommodate a user with more or less bandwidth. The menu bar that appears alongside the image viewer and flat map viewer pages allows the user to specify the size of the image (small, medium, large or huge) . The user is always presented with an initial low resolution view of an image or a map. If interested the user can access higher resolution data by pointing and clicking on the area of interest in effect "interactively" zooming into the image or the map until they reach their desired location. In this

way all of the data is made available to the students without requiring that they download more than they can accommodate at any one time. The "point and click" zooming that is evident throughout the data system makes use of a not too often seen web technique. Rather than using the more common image map method, the data system uses images as a HTML Form INPUT TYPE, which allows the cgi-bin script to capture the x- and y-coordinates of the mouse click and process those coordinates as input parameters. The user is free to select the area of interest rather than being limited by some pre-determined tiling scheme associated with the more commonly seen Image Map method. (see Figures 8 and 11)

A. Geographic Search

One of the more intuitive interfaces for Earth based image data is to place a representation (a marker of arbitrary shape and color) of the image data on a map and allow the user to move around on the map in order to access the image data found in a particular geographic location. This interface exists at many web sites, most notably the Space Shuttle's Earth Observation Image Archive at NASA Ames Research Center. The KidSat interface improves on the existing systems by providing a variety of maps on which the representations of the KidSat images are placed. Another improvement was made by placing the image markers on the map after the user view has been created by the interface. The latter change improves the accuracy of the image location on the map, because it is not fixed to the resolution of the specific map. The "on-the-fly" map generation also allows for the simple addition of different maps and additional image data as well as the updating of image data location with no extra effort. The KidSat geographic search interface allows the user to zoom in on the map of Earth simply by pointing and clicking on the map (see Figure 8). The rate of zoom can be altered by selecting "Click to Zoom In" or "Click to Zoom More" from the option menu below the map. These choices result in zooming by a factor of two or four respectively. The user can also select to see images from all or one of the KidSat missions represented on the map. And finally the user can choose either a satellite image, a topographic or a political map. The user can examine thumbnails of all of the images represented on the section of the map they are currently examining. Examining the thumbnails gives the user a preview of the contents of the image prior to viewing a higher resolution version of the image. The user can skip this thumbnail preview and select a particular image on the map by setting the option menu below the map to "Click to Look Here" and clicking on or near a particular diamond representing the image of interest. This technique can be frustrating if the user is interested in a cloud free image and is not familiar with the data. The "Click to Look Here" offers no preview of the image and the user can potentially click on or near several cloudy images before finding a satisfactory image.
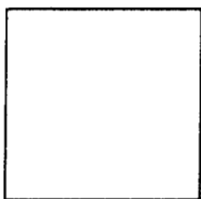

Figure 8: This set of images shows a progression of zooms, the upper left shows the entire map (488 images represented), upper right zooming in a factor of four (Click to ZOOM in More) on Australia (138 images), lower left zooms in another factor of four on the south of Australia (31 images) and the lower right a final factor of two (11 images). Each of the diamonds represent a KidSat image and are located at the center latitude and longitude for that image.

Subsequent to the initial development of this interface several "bells and whistles" were added to this page. The user can generate an animation showing the sequence in which the images were acquired be selecting the "Animate Dots" button. This tool generates an animated gif file that demonstrates the order in which the images were captured. The animation repeats until the user stops it.

B. Form Search

A form is used to search for images by creating a query based on the meta-data in the database. The form allows the user to search on either a range of values or a specific value for each of the meta-data attributes. More than one attribute may be used to define the search. For example, a query could be: find all images that have a center latitude between 15 and 40 degrees North and a shutter speed of 500. Other common examples of form search queries include: searching for all the images requested by a particular school, finding all the images within a particular Mission Event Time (MET) range or finding all the images from a particular orbit.

Once the search parameters have been defined, the form is submitted to a cgi script, asking that the resulting set of images be displayed in one of 4 presentations:

- Display Thumbnails - display the thumbnails of the images along with the image's name and information concerning any annotations and explorations for the images,
- Display on Flat Map - send the set of images to the flat map viewer, show the geographic distribution of the query result,
- Image Count - show only the number of images selected,
- Fetch Images - convert copies of the images selected to the specified format (gif, pict, jpeg) and places them in a directory available to an ftp account.

All the pages displayed as a result of the search form submittal are generated by a single cgi-script.
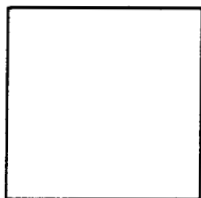
Figure 9: This screen capture demonstrates how multiple images are displayed as "thumbnails" in order to allow the user to page through a larger number of images in a shorter amount of time. The format was chosen knowing that many schools utilize 13" monitors. The 3 by 3 grid and control fit neatly on a VGA monitor.

If the **Display Thumbnails** submit is chosen, the thumbnails and accompanying text are displayed in a 3 by 3 grid, with the thumbnail and text for each image in a single cell (see Figure 9). Within each cell, clicking on the thumbnail brings up the image viewer with just that image shown, and clicking on the text under the thumbnail fetches all available meta-data for that image (including annotations and explorations) from the database.

The thumbnail display and the complete meta-data listing for an image is also available from the flat map viewer. All meta-data pages are time stamped with the time of retrieval from the database, so they may be used as hard copy records.

C. List Images

A derivative of the Form Search the List of Images was created in response to a request from a member of the KidSat Project. The request was made for a text-based list of all of the currently available images and maps. The request evolved and the list now allows the user to display either a text or image based list of all the images or a user defined subset of the KidSat images. If the list is text based, the resulting list can then be sorted by MET, latitude, longitude, orbit number or description simply by clicking on the heading of that column. Additionally, the text within the Description field can be used as keywords to search the list for all the images that contain that particular word in their Description field. For example, if a user sees an image whose Description field contains the word **America** and they want to see all the other images that contain **America** in the description they would simply click on the word **America** and the resulting list would contain only images with **America** in the

Description field (see Figure 10). In addition to the text-based list the user may opt for an image-based list. If this option is selected the user is presented with a screen-full of thumbnail images.(see Figure 10). The list generation and processing is carried out by a cgi-bin Perl script that interacts with the database holding all the meta-data for the KidSat images, generates the resulting list and the necessary HTML wrapping.
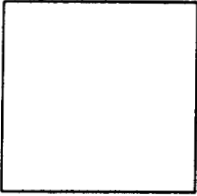

Figure 10: The List Images page is shown in both text-based mode (top) and image-based mode (bottom). The text-based list gives links to all the available data associated with an image. In this case the Description column has been limited to images containing the word "America". The image-based list link only to the images but is the most effective method to view long sequences of images. These two rows of images show a ground track over the El Niño related fires in Indonesia and then continuing over Northwestern Australia. These images were taken with the KidSat camera in the fall of 1997.

D. Latest Images

As the image data were returned from the Shuttle during the mission, users were interested in looking at the most recent images to be added to the Data System web site. The Latest Images page was developed to fill this need. The list of images is generated simply by looking in the images directory and creating a reversed time ordered list. This list is then fed to a cgi-script that generates a series of thumbnail pages in the same 3 by 3 grid referred to in the Form Search section above.

E. Image Viewer

Once a user has selected an image it is presented on the Image Viewer page which presents a low resolution version of the entire image to the user. The size of the window in which this low resolution image is presented is adjustable so it may changed to best suit the users' rate of access to the Internet. Although the user is initially shown a low resolution version of the entire image they can access higher resolution data by pointing and clicking on the image. Each successive click on the image zooms the user by another factor of two into the image (see Figure 11). The user if they choose to can zoom beyond the resolution of the data and observe the
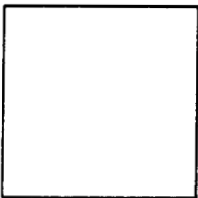
Figure 11: This progression demonstrates the click and zoom capability of the Image Viewer page. Moving from left to right more and more detail is seen in the data. This image is nearly 120km wide, making one pixel approximately 40m. Knowing the size of the image the students could then begin to measure and quantify features seen in the image.

individual pixels that make up the image. The Image Viewer brings together all the data associated with the KidSat image being displayed (see Figure 12).

In addition to the image data itself the user can access (via the link titles in parentheses):

- the meta-data (Detailed Information),
- the weather data (Cloud Cover),
- the JNC, satellite and elevation map data (Surrounding Area Map) (based on the calculated center latitude and longitude of the image),
- other nearby KidSat images (Nearby Images),
- annotated images created by the students for this image (Annotated Images) and even
- nearby Shuttle images taken by astronauts as part of the Earth Observations Program (EOP) (Nearby Shuttle Images).
- *Vote for this Image* allows students to cast votes for their favorite images.

All of these options are presented to the user as links on the image viewer page. All of these supporting data sets attempt to provide the user with a rich visual context that helps them better understand, interpret and explore the original KidSat image.

Selecting the Cloud Cover link allows the user to see the geographically related section of the global weather image data that was captured near the time that the KidSat image was taken. This weather data provides a temporal and geographical context for the image data. By zooming out on cloud data the user can see larger clouds patterns in the area surrounding the location The Data System also allows the user to animate the weather data by creating an animated gif file composed of a sequence of weather images nearest in time to the original cloud cover image selected This short animation allows the users to understand the directional flow of the cloud cover in the area surrounding the image they are examining.
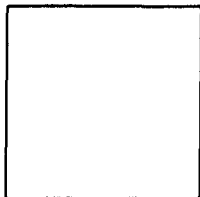
Figure 12: The Image Viewer Page and the links available directly off of the page demonstrate the amount of information associated with a single KidSat image. By pointing and clicking on the image itself the user can zoom in on the image and access higher resolution data. The image shown here is again STS086.ESC.08023638.

Selecting the Surrounding Area Map allows the user to see the JNC and the Satellite map surrounding the selected KidSat image. As discussed earlier the JNC is created based on the calculated center latitude and longitude of the image, which is based on the Shuttle position and orientation at the time the image was captured. When the JNC is created the latitude and longitude of the corner points of the map are saved and used to create the Satellite and elevation maps. By creating the latter two maps based on the JNC, the generation of three co-registered, geo-referenced data sets is guaranteed. When selecting any of these maps a new link appears in the menu bar to the right of the image. The link **Add KidSat Image** composites the KidSat image on top of the map data the user is displaying. This compositing is carried out using the scale and look direction values in the meta-data and then using the netpbm routines to scale, rotate and composite the image on top of the map image data. The resulting "layered" data set allows the user to see how the different image data sets are related and also the significance of the meta-data. Furthermore by selecting an image from the list of images that have not been combined with their maps the user can interactively register the image data to the map data using server side cgi-scripts that translate and rotate the image on the underlying map (see Figure 13). The user can also adjust the transparency of the image using this interface, to see more or less of the map image through the KidSat image. Once the registration of the two data sets is complete the translation and rotation information is saved on the server so that the work is not repeated in the future. The registered data set is then added to the list of combined image and map data sets. Although most student users do not have the access to the Internet that would make this registration process tolerable it was created as a means to divide a labor intensive task up among an unlimited work force and allow those who were able a chance to interact with the various data sets.
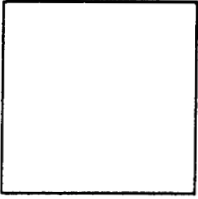
Figure 13: Image Composer page allows users to interactively register the scaled and rotated KidSat image on top of the either the satellite map or the JNC map. The controls allow the user to translate and rotate the image. The opacity of the image on the map can also be changed from 50-100%.

If an elevation map is available for the particular KidSat image the user can create a VRML 3-D textured landscape by selecting the "[3D VRML]" link to the left of the map image. If the user has the appropriate browser plug-in they can then manipulate the area of interest in 3-D space. The VRML plug-in allows the user to pick one of five viewpoints (North, South, East, West and Top) and allows the viewer to interactively zoom in on any part of the landscape. The landscape is created by turning the elevation data into a VRML 2.0 elevation grid node and then using the current map or map-image composite displayed on the web page as the texture map to drape over the elevation grid.

F. Download Images

The users can at anytime choose to download the image they are displaying whether it is the original image or the weather or map data. The download page allows the user to specify the size and file format of the image to be transferred to their local computer. The netpbm routines are used to scale and convert the images on the server to the user specified size and file format. The delivery of the image data to the students through this mechanism was a major weakness of the system. If a teacher wanted to download a sizable number of images, they were forced to either download them one-by-one or use the form search to specify their set of images and then select "Fetch Images" to start the query. This latter method was only created in response to negative feedback about downloading files one-at-a-time.

G. Image Processing Tools

Once the images and meta-data have been made available, the responsibility of the Data System becomes one of providing tools, technology and support to the students and the teachers so that they may fulfill their responsibility as image explorers. NIH Image was selected as the image processing tool for the classroom because:

1. it was free,
2. members of the curriculum design team had experience with it and
3. it provided a means to carry out quantitative analysis of the image data.

The program is capable of carrying out many image processing tasks. Most significant to KidSat teachers was the programs ability to measure distances and areas. Students also used NIH Image to annotate the images, labeling features and indicating orientation with a north arrow graphic. NIH Image also allows for the development of custom macros. Using the macro language a series of steps may be carried out with a single menu selection. A beta version of the program is now available for the PC platform. Unfortunately for KidSat this PC version was not available during operations. Classrooms without Macintosh computers were unable to take advantage of some of the benefits of NIH Image.

H. Uploading Student Work

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In order to assess the success of the project and its curriculum the Data System constructed the means by which the students could send data back to the Data System. Students could send in information as Image Validations, Image Annotations or Image Explorations. In order to expedite this process the Data System constructed forms that allowed the students to enter updates to the meta-data, annotated images or explorations. This ingestion of data supplied by students was the trickiest part of the web page/database interaction. The three forms associated with this were:

- Principal Investigator (PI) Validation
- Image Annotation
- Image Exploration

Each type of meta-data had its own form, and headaches. PI Validations could only be submitted by the school or schools that requested the image be taken, and each school may only submit one validation per image. If a specific school submitted a validation for the same image twice, the second submittal was considered an update of the first. The only data uploaded was meta-data on the form itself. Annotations and explorations could be submitted by any student from any participating class. Not only was meta-data from the form uploaded, but so are images and text files. Perl programs created directories and files, converted images, verified meta-data syntax as well as inserting data into the database. If the submittal was successful, a time stamped page was generated showing the meta-data that had been placed in the database.

Meta-data could be supplied for a submittal, updated and resubmitted several times. A way to allow students to save a copy of the submittal form was needed. The solution was to write a Perl program to generate all submittal forms. If an individual chose to save the form and its data, the form was submitted and this program was passed the uploaded data from the cgi-script. It generated a new form for the browser with the data in the appropriate fields. The user then saved this form to a local file, opened it the next time the data were to be resubmitted, made the desired modifications to fields on the form, uploaded it, and could save this form again. One drawback was that filenames specified on the forms were not saved. Some teachers misunderstood what saving the contents of the form meant, confusing it with actually uploading the information.

As this concept of placing web form supplied meta-data into the database was developed, three areas of major concern became apparent:

- maintaining the integrity of the meta-data from the telemetry and image headers,
- preventing students from overwriting each others submittal,
- verifying the validity of the students' input before allowing it to be viewed from the database search pages.

The solution was to place this meta-data in it's own tables and not allow updates to any of the telemetry or image header meta-data by student supplied data. The student supplied data were placed in temporary tables until the teachers could verify it. This meant, that a whole set of forms for the teachers were needed. These forms allowed each teacher to verify all submittals from their class, and only those submittals. For each submittal, the forms allowed the teacher to view the meta-data and images submitted, see what previous submittals, if any, this submittal would overwrite, and either accept the submittal or delete it.

Examples of the student submitted validations, annotations and explorations can be found on the web associated with their original KidSat image. Student members of the exploration team also generated explorations. A list can be found on the Exploration Web Pages.

VII   Conclusions

In general the KidSat Data System should be considered a major success. The KidSat images were provided to students and teachers in a timely manner via the Internet. Supplementary data sets were made available to provide insights into the data. Students and teachers were provided with limited tools allowing them

to continue to work with the images on their classroom computers. Finally, the students were given a means to return their work to the Data System so that it might be shared with fellow KidSat participants on the web. This success was achieved in large part due to open communications between the various elements involved in the KidSat Project. Teachers, students and fellow staff members would offer suggestions to improve the Data System. In nearly all cases these suggestions were then integrated into the working Data System. This resulted in a very dynamic, feedback driven system. Additionally, having the opportunity to visit classrooms, see the installed technology base, talk to students and teachers and explain how the Data System worked was an invaluable input mechanism for further design updates. However, given a second opportunity there are many things that the Data System could improve upon. It would have been beneficial to the students and teachers, if efforts had been split and a second Data System that was not completely dependent on the Internet had been produced. It became obvious whenever working with a teacher or a student on a classroom computer that access speeds were not sufficient to make complete use of the Data System capabilities. A CD-ROM based product could have delivered to students and teachers a subset of the capabilities of the on-line system and tied-in where necessary to the Internet. The CD-ROM could not provide the immediate access to the data during the mission, but would allow the teachers and students to have local access to most of the data within a matter of weeks of the completion of a mission. The total reliance on the Internet to deliver large amounts of static image data to students in schools was frustrating for both the students and the teachers. Access to computers and the Internet has not developed to the point where it is fair to expect a classroom teacher to spend the time needed to fully explore and interact with a site like this one. Ideally, using a CD-ROM, all the static image data could be delivered to the classroom at one time (within weeks of the completion of a mission). Browsing the web to look for images of interest would no longer be necessary. More time could now be spent working on selected images and then returning to the Data System the image validations, annotations and explorations. Secondarily, by wrapping the contents of the CD-ROM in HTML, the Data System interface could be learned without having an Internet connection. Better documentation and communication of capabilities and processes also may have helped generate better results in the form of image validations, annotations and explorations. Although every effort was made to communicate with teachers via Summer Teacher Training Sessions and teleconferences, it is obvious given the amount of data that came back to the Data System that there was something missed. Perhaps the upload system was made too difficult.

The Data System web site can be visited at http://kidsat.jpl.nasa.gov/datasys/ Feedback is accepted and acted upon when deemed appropriate. Please feel free to visit the site and make suggestions for changes. The KidSat Data System brings together a broad collection of data from a variety of sources and presents them in a unique way. It is hoped that users will continue to enjoy the system as much as the designers and implementers enjoyed working on it.
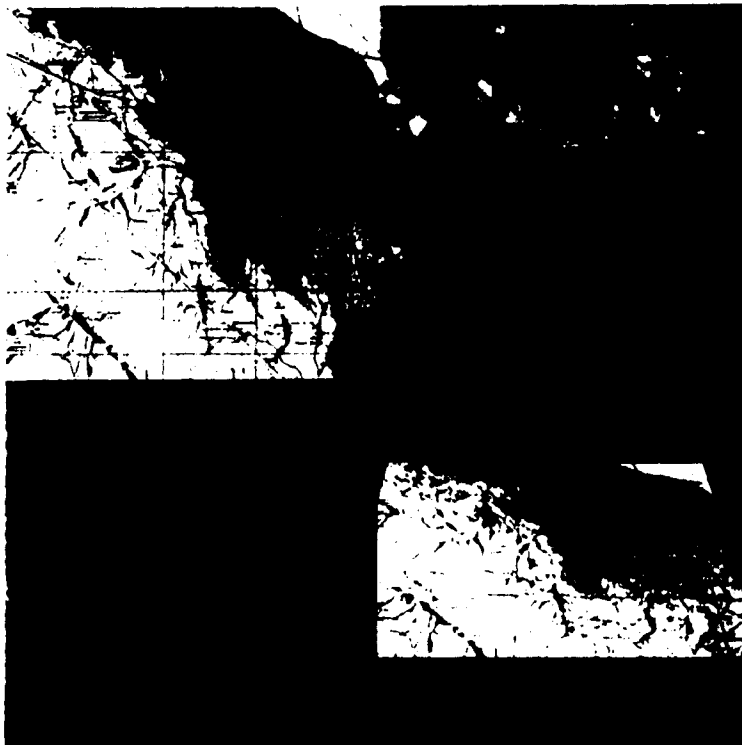
Acknowledgments:

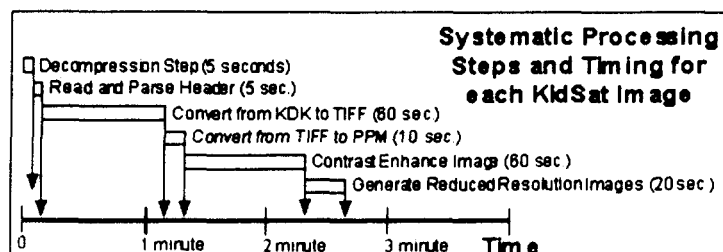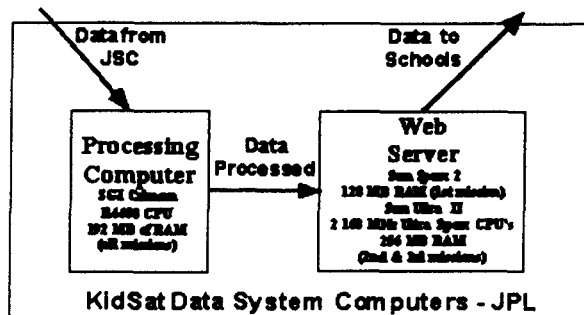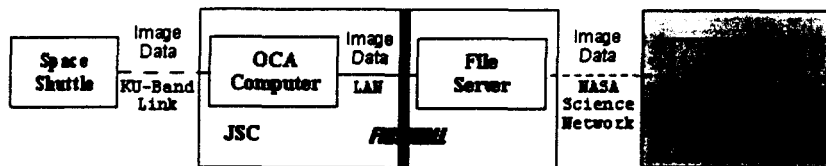Grace Kim and Lisa Yiu. The teachers who contributed to the Data System are John McGuire, Bruce Fisher, Roger Kassebaum, Kathy Rackley, Mark Jones, Rie Cowan, Patti Compeau, Paul Bixler, and Richard Anderson. Thank you all teachers, students and JPL personnel for you unwavering support of this project. One special last thank you to the mother of KidSat Dr. JoBea Way for all of her incredible enthusiasm and energy. It would never have happened without you.

The Data System web site can be visited at http://kidsat.jpl.nasa.gov/datasys/ Feedback is accepted and acted upon when deemed appropriate. Please feel free to visit the site and make suggestions for changes. The KidSat Data System brings together a broad collection of data from a variety of sources and presents them in a unique way. It is hoped that users will continue to enjoy the system as much as the designers and implementers enjoyed working on it.

6

Space Shuttle — Image Data / KU-Band Link → OCA Computer — Image Data / Sneaker Net → Internet Computer — Image Data / NASA Science Network

Johnson Space Center

Space Shuttle — Image Data / KU-Band Link → OCA Computer — Image Data / LAN → File Server — Image Data / NASA Science Network

JSC   Firewall

Data from JSC →

Data to Schools →

Processing Computer
SGI Chanus
R4400 CPU
192 MB d'RAM
(all missions)

Data Processed →

Web Server
Sun Sparc 2
128 MB RAM (1st mission)
Sun Ultra II
2 140 MHz Ultra Sparc CPU's
256 MB RAM
(2nd & 3d missions)

KidSat Data System Computers - JPL

Systematic Processing Steps and Timing for each KidSat Image

Decompression Step (5 seconds)
Read and Parse Header (5 sec.)
Convert from KDK to TIFF (60 sec.)
Convert from TIFF to PPM (10 sec.)
Contrast Enhance Image (60 sec.)
Generate Reduced Resolution Images (20 sec.)

0   1 minute   2 minute   3 minute   Time

KidSat DataSystem
Color Image
Thumbnails

Next Page

Go To Page

Annotated Image   Nearby Images   Cloud Cover

Image Viewer Page and Links

Image Viewer
Menu Bar

Image Locator Map

Center Lat. & Lon

Nearby Shuttle
Mission Images

Vote for this Image

Select Display Size

Select Image MET

Detailed Information   Surrounding Area Map   Download Image

EarthSat Image Composer